Specialized Optical Coating Solutions for Astronomical Instruments

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The performance of specialized astronomical instruments can often be greatly enhanced by the implementation of specialized optical coating solutions. These solutions may include the design and subsequent deposition of unusual multilayer coatings composed of dielectric materials, metals, or combinations of the two. Wavelength selective transmission coatings may be combined with specially designed reflective coatings in the same instrument in order to obtain the desired performance characteristics. The various coating design options, when included as a part of the initial system design, can be utilized to produce an instrument with optimum spectral and polarization response. In some cases, it is desirable to tune the optical properties of specific coating materials using process parameter modulations in order to obtain elements with demanding optical characteristics. The physical properties of coatings are characterized through the use of advanced surface morphology equipment such as atomic force microscopes, surface profilometers, and spectrophotometers.

A significant portion of the coating and surface morphology research conducted in the Optical Fabrication Branch at MSFC is directed toward the development of unique coating design solutions for optical systems with demanding performance characteristics. A Center Director’s Discretionary Fund project initiated October 17, 1995, entitled “Development of Polarization Optics for High-Resolution Vector Magnetic Field Measurements,” encompasses the development of wavelength selective transmission filters, reflective mirrors, and beamsplitters which introduce minimal instrumental polarization effects. One instrument which will benefit from this effort is the Experimental Vector Magnetograph (EXVM),[1] shown in figure 107. Scientists at MSFC’s Space Sciences Laboratory use this instrument to characterize the magnetic field of the Sun by measuring the polarization of light in iron ion absorption bands at 525 and 630.2 nm wavelengths. Light associated with the hydrogen-alpha line at 656.3 nm is also measured. A separate submission to the *1996 Research and Technology Report* by John Davis et. al. describes the use of wavelength selective mirror coatings designed to reflect light around the spectral regions described above while rejecting significant amounts of infrared, and in some cases visible, radiation. Development of a full aperture prefilter and a specialized beamsplitter has also been initiated. These optics will be coated in the near future in the existing 30-in Balzers coating system which is equipped with a Temescal four-pocket electron beam evaporation source and a advanced thin film optical monitor.

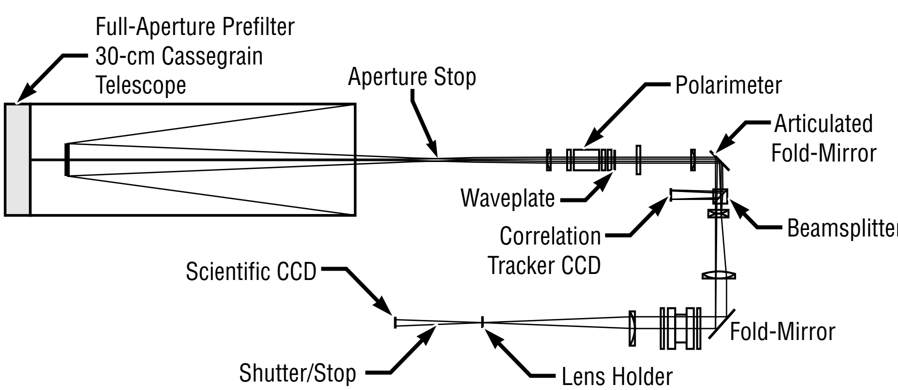

FIGURE 107.—Schematic of the Experimental Vector Magnetograph at MSFC. Specialized optical coating solutions are being applied to develop a full-aperture prefilter, specialized infrared transmitting nonpolarizing mirror coatings and a nonpolarizing wavelength selective beamsplitter which is used with the image motion compensation correlation tracker.

The EXVM beamsplitter is required to direct some of the light from the instrument into a motion compensating correlation tracker charge coupled device (CCD). The majority of the polarization sensitive light must be directed to the scientific CCD with an instrumental induced polarization of 0.1 percent or less. These requirements led EB52 personnel to design a specialized cube-type beamsplitter containing a specially designed all-dielectric coating. The transmission of the beamsplitter as a function of wavelength is shown in figure 108. It is clear that the design shown meets the requirements very well. There is very little separation between s- and p-polarized components of the transmitted light at the polarization-sensitive wavelengths. About 20 percent of the randomly polarized light around the hydrogen alpha line is reflected to the tracker. The difficulty of designing useable nonpolarizing cube-type beamsplitters, formed by cementing one coated and one uncoated right angle prism together, is described by Macleod.[2]

A National Research Council Fellow, Dr. Naba K. Sahoo, stationed at MSFC is investigating the properties of some specialized dielectric coating materials which may facilitate the design and fabrication of optimum broadband antireflection coatings and filters useful for numerous astronomical missions. Preliminary results indicate that optical properties of these materials can be modified via process parameter changes thus yielding inhomogeneous or graded index films. The films are being characterized via advanced surface morphology equipment such as the Optical Fabrication Branch's atomic force microscope. Dr. Sahoo is also developing specialized computer algorithms to model inhomogeneous coating designs and to predict the sensitivity of multilayer coatings to variations in individual layer parameters.

The utilization of specialized optical coating solutions for applications listed above, as well as other NASA and commercial applications, is expected to result in the fabrication of instruments that would not be possible by other means. Designers of optical instruments can now consider the use of nontraditional coating designs and exotic materials in order to meet the demanding requirements of future NASA programs.

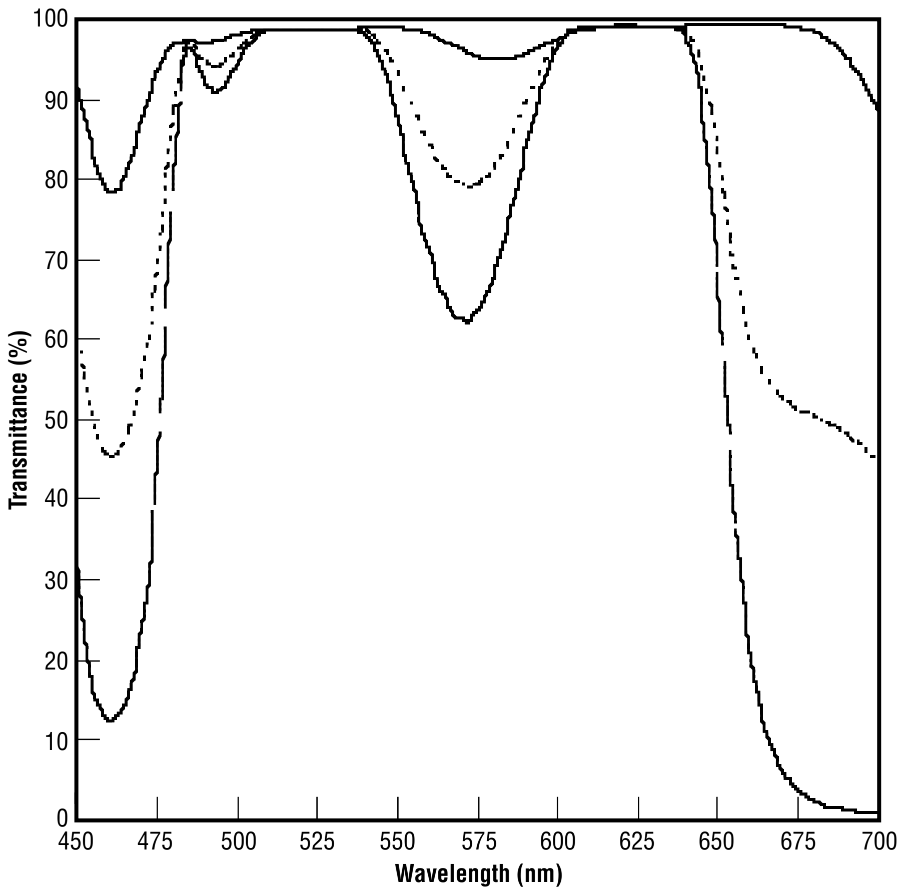

FIGURE 108.—This graph shows the expected transmittance as a function of wavelength for a cube-type beamsplitter containing an MSFC-designed all-dielectric coating. This beamsplitter is designed for use in the Experimental Vector Magnetograph at MSFC. The three curves indicate the transmission for light with three types of polarization. The top curve (solid) corresponds to p-polarized light, the middle curve (dotted) to random or unpolarized light, and the bottom curve (dashed) to s-polarized light.

[1]West, E. and Smith, M.H.: "Polarization Characteristics of the MSFC Experimental Vector Magnetograph." Polarization Analysis and Measurement II, *SPIE* vol. 2265, pp. 272–283, 1994. (Proceedings 1994 SPIE International Symposium on Optics, Imaging, and Instrumentation, San Diego, California, July 24–29, 1994).

[2]Macleod, H.A.: "Thin-Film Optical Filters." Macmillan Publishing Company, New York, 1986, pp. 148–154, 334–342.

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Biographical Sketch: Dr. Alan Shapiro is a coating physicist at the Optics and Radio Frequency Division at MSFC's Astrionics Laboratory. He conducts research on specialized optical coatings, many of which are utilized for astronomical and astrophysics related programs. He also conducts research on the surface morphology of material surfaces. Shapiro earned his Ph.D. in condensed matter physics from the University of Illinois, Urbana-Champaign in 1987, after which he worked at International Business Machine Corporation, East Fishkill, NY. He has worked for NASA at MSFC since May 1989.

Edward West is a solar physicist in the Physics and Astronomy Division at MSFC's Space Sciences Laboratory. He worked at Johnson Space Flight Center as a solar observer during the Skylab missions. After the Skylab missions, he was transferred to the Solar Physics Branch to work with the vector magnetograph project. Since that time he has worked in both the hardware and software development of the vector magnetograph. His main research interests have been in the development of stable, high-resolution polarimeters for both ground-based and space-based solar magnetographs, in the development of real-time analysis techniques to be used in flare prediction, and in studies relating polarization measurements to magnetic field evolution and magneto-optic effects in sunspots.